Biological soil crust in Peru: first record and description

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ABSTRACT
The presence of biological soil crusts in the Andean and coastal regions is reported for the first time in Peru. Crusts dominated by cyanobacteria, lichens and/or mosses are described from localities in the coastal desert (Lomas) and in the high Andean region (Puna).

Keywords: Andes, Lomas, Puna, Pacific coastal desert, soil biocrust.

INTRODUCTION
Desert crusts or biological soil crusts (BSC) are key features of earth’s arid ecosystems composed of biotic layers of cyanobacteria, bacteria, algae, fungi, lichens, and bryophytes that cement the loose soil particles of the desert soil (Belnap & Lange, 2003). BSC occur in most arid and semi-arid regions of the world where account for a substantial amount (~70%) of the living cover (Belnap & Lange, 2003). In spite that Peru has about 328,093 km² of arid and desert lands (Ministerio del Ambiente, 2012), biological crusts have never been described or reported from Peruvian deserts except for indirect references of soil lichen communities in several Andean localities (Ramírez & Cano, 2005) and the called “loma de Nostoc” in coastal deserts (Ferreyra, 1953).
The lack of information on Peruvian BSC’s is an important gap given the key role that desert crusts play on terrestrial ecosystems such as soil stabilization, erosion control, nutrient fixation, and as facilitators for the establishment of higher plants in arid environments (Malam et al., 1999; Belnap et al., 2003; Thomas & Dougill, 2007; Guo et al., 2008). Arid ecosystems along the Peruvian coast possess a high level of endemism, and thus it is necessary to understand how the occurrence and functional relationships of Peruvian BSC influence species and communities of high conservation value. Here we provide the first report and description of BSC in Peru from localities in the coastal desert (Lomas), and in the high Andean region (Puna).

Structure and function of Biological Soil Crusts (BSC)
BSC develop on the open ground surfaces of arid environments and play an important role in sustaining life in the world’s driest terrestrial ecosystems (Concostrina-Zubiri et al., 2013). BSC result from an intimate association between soil particles and cyanobacteria, algae, microfungi, lichens, and bryophytes which live within, or immediately on top of, the uppermost millimeters of the soil (Belnap et al., 2003). Soil particles become aggregated through the presence of polymeric exudates and continuous growth of this biota, resulting in a hardy layer on the ground’s surface (Belnap et al., 2003). BSC most often occur in areas of extreme temperatures, high levels of solar radiation, and prolonged dry periods (Belnap et al., 2003). BSC have been found worldwide in almost all arid and semiarid microclimates and biomes (Büdel, 2003).

BSCs contribute to soil carbon and nitrogen fluxes and modulate water infiltration and storage, directly affecting the structure of vascular plant communities and their consumers (Belnap & Lange, 2003). For example, cryptogamic covers that include BSC are estimated to contribute ~7 % of the annual global carbon sequestration by terrestrial biota and ~40 % of annual biological nitrogen fixation (Elbert et al., 2009, 2012). Although studies on biological and ecophysiological aspects of BCSs has increased in recent years (Concostrina-Zubiri et al., 2013), there is a huge information vacuum regarding BSCs and their biotic interactions with vascular plants, invertebrates, and vertebrates (Castillo-Monroy & Maestre, 2011).

Biological soil crust in Peru
BSC can be formed in arid and/or cold regions of Peru where vegetation is sparse. Here we report BSC from four sites, two in the high Andean region above 4000 m in the “Puna” around of Huayllay (11°00’S – 76°23’W, annual temperature 3.8°C, precipitation 245.9 mm) in Pasco, and around of Juliaca (15°30’S – 70°09’W, annual temperature 9.5°C, precipitation 615.0 mm) in Puno (Figs. 1 a-c). The other two are in the coastal desert of the Pacific within the so-called coastal Lomas, one in “Lomas de Lachay” (11°22’S - 77°22’W, annual temperature 14.9°C, precipitation 210.0 mm) and around of Barranca (10°45’S - 77°40’W, annual temperature 18.9°C, precipitation 4.0 mm) both in Lima (Figs. 1 d-j).
Biological soil crust in Peruvian Andes

The Peruvian Andes are one of the most geographically complex environments in the world, with areas of great altitudinal variation and extreme humidity differences, forming a varied mosaic of different landscapes. It is in the area considered as “Puna”, distributed between 3300 and 4500 m altitude, where conditions for the development of BSC are presented. In the “Puna” the low temperatures and the long dry season determine the development of scattered vegetation in most of the area, being characteristic the grasslands. Another area of particular importance is present around the high mountain areas, below the snow line, where the rocks make micro environments occupied by a particular flora. On bare soil between the sparse vegetation and rocks the BSC is established (Fig. 1a).

Although different types of BSC have a complex distribution pattern in the landscape of the “Puna”, it is observed that in general BSC are dominated by lichens in the drier areas around rocks and stones (Fig. 1b), while mosses dominate the cover in wetter areas between tussocks of grasses (Fig. 1c).

Biological soil crust in coastal Peruvian “Lomas”

The Peruvian desert is a narrow hyper-arid band confined to the coast that extends 2,000 km (5°-18°S) and covers about 9.4% of Peru (120,651 km²). Biodiversity hotspots with a high percentage of endemic species that specialized on extreme aridity are common throughout this vast desert fringe (Rundel et al., 1990, Arana & Salinas, 2007). The coastal landscape is dominated by alluvial flats, but areas with small mountains condense the winter sea fog, providing moisture and supporting seasonal plant communities called “Lomas” (Rundel et al., 1990; Arana & Salinas, 2007). We have recorded the extensive occurrence of BSCs in these ecosystems (Fig. 1 d).

In Lomas ecosystems, humidity increases with elevation, creating a gradient that strongly influences the characteristics and composition of BSCs (annual temperature 17°C and precipitation 100 mm). From 150-350 m above sea level a BSC dominated by cyanobacteria first appears (Figs. 1 e and f). From 350-400 m lichens become the dominant cover (Fig. 1g). Above 400 m in Lachay, BSCs are dominated by mosses (Fig. 1 j), but noting that areas with dense scrublands lack BSC. Nevertheless, variability in the relationship between elevation and BSC type should be expected among different Lomas sites. This is because factors such as aspect, slope and distance to the ocean can create different humidity values on different Lomas sites.

Perspectives for future BSC research in Peru

Although many BSC from subtropical to Polar Regions have been described in recent decades (Belnap & Lange, 2003; Türk & Gärtner, 2003; Büdel, 2005; Karsten & Holzinger, 2014) little is known of tropical BSCs. It is remarkable that in Peru there are no previous studies on the BSC. Thus, BSC studies ranging from basic structural and taxonomic characterizations, distributional ranges, nutrient fluxes, and interactions with higher taxa are warranted. BSCs have been reported to be “ecosystem engineers” in other arid regions with important roles in primary productivity, nitrogen and carbon cycling, mineralization, water retention,
and stabilization of soils (Evans & Johansen, 1999; Reynolds et al., 2001; Lewis, 2007; Karsten & Holzinger, 2014). It is likely that much of Peru’s arid and semiarid ecosystems and their high endemism depend directly or indirectly on the presence of BSCs.

For example, a recent review shows that BSCs contribute to fixing about 7% the carbon and 46% of the nitrogen in terrestrial ecosystems (Elbert et al., 2012). But in large areas like the Peruvian high Andes and the coastal deserts, the contribution of BSCs to carbon and nitrogen fluxes is not known yet. It is also important to conduct studies addressing the relationships between higher plants and animals, and how BSC structure and function relates to plant and animal community diversity and structure. The unique characteristics of the Peruvian coastal desert and high Andes biomes makes it difficult to extrapolate knowledge from other systems, creating a strong need for local field studies.

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REFERENCES


Figure 1. (a) Andean landscape where BSC develop among tussocks of grasses, (b) Andean BSC dominated by mosses, (c) Andean BSC with dominated by lichens, (d) Coastal Lomas landscape with BSC visible as an widespread dark layer on the soil, (e) Vertical profile and (f) top view of coastal BSC with cyanobacterial dominance, (g) Top view and (h) vertical profile of coastal BSC with lichen dominance, and (i) coastal mixed BSC of cyanobacteria and lichens, (j) coastal BSC dominated by mosses.
Figure 2. Map of distribution of BSC in South America (after Büdel 2003).
**Figure 3.** Map of areas with potential presence of BSC in Peru (black areas with reports of field, gray areas with suspect of sparse presence).